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Women's implicit bias against threatening male faces: The role of emotion, hormones, and group membership

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1. Introduction

Evidence suggests that women's sensitivity to interpersonal threats varies across the menstrual cycle. Because conception risk is higher during the fertile phase of the cycle, women may be more biased against aggressive, physically threatening men due to the high cost of sexual coercion (Bröder and Hohmann, 2003; Chavanne and Gallup, 1998; Garver-Apgar et al., 2007). In addition, during the luteal phase, when the maternal immunity shifts (presumably to protect the potential blastocyst), women may be more avoidant of pathogens, including those transmitted by conspecifics (Fessler and Navarrete, 2003; Fleischman and Fessler, 2011; cf. Jones et al., 2018). In the present work, we sought to test how variation in two reproductive hormones (i.e., estradiol and progesterone) is related to variation in women's implicit attitudes toward the faces of ingroup and outgroup men in a minimal-group context. Examining these hormones simultaneously allowed us to better understand how women respond to ingroup versus outgroup men with cues to infectiousness versus violent intent.

1.1. Fertility and avoidance of sexual coercion

Sexual coercion by men has arguably been a recurrent adaptive problem to women across human history (McKibbin and Shackelford, 2011). As such, women have likely evolved different psychological mechanisms for neutralizing men's unwanted sexual advances (Bröder and Hohmann, 2003; Chavanne and Gallup, 1998). Due to the potential costs of pregnancy and lactation, women might invest more in the avoidance of particular men when sexual coercion carries the highest reproductive costs – specifically, when conception risk is high (Lieberman et al., 2011; McDonald et al., 2015). This hypothesis has been supported by multiple studies, which have reported that when conception risk among women is the highest, women (1) are more sensitive to cues of male sexual coerciveness – for instance, they perceive unacquainted men as more coercive (Garver-Apgar et al., 2007), (2) feel physically stronger, which might encourage defensive aggression against men (Prokop, 2013), and (3) take fewer risks, potentially to avoid coercive men (Bröder and Hohmann, 2003; Chavanne and Gallup, 1998).

That said, this literature is handicapped by its assessment of conception risk, with most studies employing between-subjects designs that estimate conception probability using forward or backward counting methods, both of which have low validity as assessments of conception probability (Gangestad et al., 2016). Indeed, Gangestad and colleagues recommend assessment of reproductive hormones (i.e., estradiol and progesterone) and the use of within-subject designs to test the types of hypotheses described above. We did so in the current study. Specifically, we predicted that, as estradiol-to-progesterone ratio (referred to as E/P ratio, a state coinciding with high fertility, Baird et al., 1991; Roney, 2018) shifts within women, so too should their biases against physically threatening men.

1.2. Reproductive hormones and pathogen avoidance

The threat of pathogen transmission and infectious disease has been a long-standing challenge across human evolutionary history. Previous research suggests that the costs of infection may also change across women's menstrual cycle. Specifically, the compensatory behavioral prophylaxis hypothesis suggests that, during the luteal phase of women's menstrual cycle, progesterone increases are associated with suppressed maternal immunity; these changes putatively facilitate tolerance of the foreign body implanted after conception (Fessler, 2001; Fessler and Navarrete, 2003; Fleischman and Fessler, 2011). Because of such immunosuppression, women should engage in more compensatory behavioral prophylaxis – that is, actions to prevent infection – during the luteal phase of the cycle. One study has indeed found that progesterone is associated with more self-grooming behaviors like scratching and greater disgust toward pathogen cues (Fleischman and Fessler, 2011, cf. Fleischman and Fessler, 2018, Jones et al., 2018). Another study found that when progesterone is relatively high, women attend more to disgusted faces with an averted gaze, which might give information regarding nearby pathogen threats (Conway et al., 2007). However, these studies only employed between-subject designs with relatively low statistical power. Conversely, a recent study with a within-subjects design and a larger sample size failed to find any relationship between changes in progesterone and changes of disgust sensitivity across multiple assessments (Jones et al., 2018).

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In the present research, we also applied a within-subjects design to test if women are more sensitive to pathogen threats when their progesterone levels are high. In line with the compensatory behavioral prophylaxis hypothesis, we predicted that E/P ratio, which is lowest in the luteal phase of the cycle, would be associated with more negativity against men possessing cues to infectiousness.

1.3. Threats and group membership

Not all men are equally likely to pose a sexual or pathogen threats, of course. Indeed, sexual coercion is especially prevalent during intergroup conflicts (Navarrete et al., 2010; Thornhill and Palmer, 2001; Van Vugt et al., 2007). Additionally, compared to ingroup men, outgroup men are less likely to be monitored and constrained by the ingroup norms that might punish aggressive or exploitative behaviors toward women (McDonald et al., 2011). In line with these considerations, findings suggest that increased conception risk is positively associated with implicit bias against men from racial outgroups and with implicit biases against men categorized as belonging to outgroups via the minimal-group paradigm, especially when women perceive these outgroup men as physically formidable (McDonald et al., 2011; Navarrete et al., 2009). Recently, a high-powered conceptual replication failed to support the association between conception risk and bias against racial outgroup (Hawkins et al., 2015). However, this study had multiple shortcomings as a conceptual replication, including the use of female target stimuli, which is inconsistent with the sexual avoidance account for intergroup bias, and the use of explicit measures, which may be more susceptible to social desirability compare to implicit measures (McDonald and Navarrete, 2015). The present study sought to replicate the finding of a relationship between conception status and implicit bias against outgroup men in a minimal-group context. Further, in line with recent recommendations in the ovulatory cycle literature (Gangestad et al., 2016), we measured reproductive hormones that vary as a function of conception probability rather than using counting methods based on self-reports of menstruation. We hypothesized that the association between E/P ratio and bias against aggressive male faces would be stronger against outgroup than ingroup men.

Interactions with outgroup men might also connote a higher infection risk for women compared with interactions with ingroup men, for two different reasons (Fincher and Thornhill, 2012; Tybur et al., 2016). First, due to host-parasite coevolution, women (and men) might have less acquired immunity to the novel pathogens hosted by outgroup members. Second, lacking specific cultural knowledge, outgroups may be more likely to violate local hygiene norms or customs, which serve to neutralize local parasites. Thus, we hypothesized that the association between E/P ratio and negativity toward infectious faces would be stronger against outgroup than ingroup men.

Given that high levels of E/P ratio might correspond with greater costs of sexual aggression, and that lower levels of E/P ratio might correspond with greater costs of infection, we predicted that the relationship between E/P ratio and bias against men would be moderated by the type of threat posed by the men (i.e., pathogenic versus violent). Further, given that outgroup men might be perceived as posing both a greater violence and pathogen threat to ingroup women, we hypothesized that group membership would further moderate this effect. Thus, E/P ratio should be positively related to bias against aggressive men and negatively related to infectious men, and the biases against aggressive and infectious men should be amplified toward outgroup men relative to ingroup men.

1.4. The present study

To our knowledge, no research to date has tested how reproductive hormones relate to biases against faces characterized by these two recurrent threats in a single study. The current study thus aimed to investigate how estradiol and progesterone, which systematically fluctuate across the menstrual cycle, differentially influence women's attitudes toward facial cues of violence and pathogen threats. Specifically, we hypothesized that E/P ratio would positively predict bias against angry faces, but negatively predict bias against infectious faces. In addition, we hypothesized that at higher levels of E/P ratio, which indicates high fertility, women would show greater bias against angry faces than infectious faces. In contrast, at lower levels of E/P ratio, which is lowest in the luteal phase of the cycle, women would show greater bias against infectious faces than angry faces. Further, we try to replicate and extend McDonald and colleagues' findings (2011) testing whether the relationship between reproductive hormones and bias against threatening male faces would be different against ingroup and outgroup men in a minimal-group context.

2. Method

2.1. Participants

Forty-two Dutch women were recruited from Vrije Universiteit Amsterdam. To participate, they had to: (1) have a regular menstrual cycle length of 25 to 34 days, (2) not be using hormonal contraceptives for at least three months, (3) not be pregnant or breastfeeding, and (4) be under 40 years old. One woman participated in only one of the four sessions, and her saliva sample could not be analyzed due to abnormal viscosity. She was thus excluded from analyses. Two other women had missing data for one session; their data were nonetheless analyzed. The remaining 39 participants completed each test session and provided four analyzable saliva samples. In total, then, the final sample included 41 participants (mean age = 20.22 years, SD = 3.20 years). We also assessed participants' sexual orientation on a seven-point scale, from 1 (completely heterosexual) to 7 (completely homosexual). Twenty-one participants reported being completely heterosexual, and one reported being completely homosexual. We did not exclude participants based on sexual orientation.

2.2. Procedure

Participants completed four test sessions, each approximately one week apart, over a period of four to five weeks. Each participant was scheduled to come to the lab the same day every week. However, if they could not make the appointment the same day for one session, they would be scheduled one day earlier or after instead. The procedure of each session was identical. Before the first session, participants were assigned to either a blue group or a red group by using a minimal-group paradigm. Then, in each session, they performed four single category implicit associations tests (SC-IAT; Karpinski and Steinman, 2006) in a random order. Next, they were asked to complete a survey, which included demographic questions, a voice preference task from an unrelated study, and pathogen items from the Three Domain Disgust Scale (TDDS, Tybur et al., 2009), Finally, they were asked to provide a saliva sample.

2.3. Minimal group paradigm

The minimal group paradigm is a frequently-used procedure in which participants are assigned group membership based on a random criterion such as the flip of a coin or color preference (Otten and Moskowitz, 2000; Tajfel, 1970). We based our procedure on that described by McDonald et al. (2011), who reported that estimated conception probability predicted women's bias toward outgroup men in a similar minimal group paradigm.

Before the first experimental session, participants were asked to finish a color judgment task. They were presented with three printed images of 12 × 12 grid of two colors – blue and red (see Supplementary Materials for the images). The printed images were presented for 2 s by the experimenter and followed by a question asking which color on the

grid was more prevalent. After answering, participants were assigned to either the blue group or the red group depending on which color they indicated at least two out of three times. They were then informed 'You tended to perceived more (blue/red) easier, so you are a (blue/red) perceiver'. As a reminder of group membership, participants were asked to wear two blue/red wristbands during the entire experimental session. This procedure was similar to that employed by McDonald et al. (2011), except that participants were given colored wrist bands here rather than colored t-shirts.

The assignment to groups was conducted only once before the first session. For the subsequent three sessions, the experimenter reminded the participant of her group membership and provided colored wristbands.

2.4. Angry and infectious faces

In total, forty images of twenty men posing both an angry and a neutral facial expression were selected from the Radboud Faces Database (Langner et al., 2010). The models were Caucasian males wearing black t-shirts. In the first pilot study, 46 participants rated how physically threatening, physically strong, and attractive each face was on 9-point scales. The ten angry faces that were rated highest on physical threat were selected and then evenly divided into two groups equated for ratings of physically threatening ($M_{red} = 4.97$, $M_{blue} = 4.84$, $t(45) = 0.30$, $p = .297$, $d = 0.084$), physical strength ($M_{red} = 5.05$, $M_{blue} = 4.98$, $t(45) = 0.85$, $p = .401$, $d = 0.065$), and attractiveness ($M_{red} = 3.71$, $M_{blue} = 3.89$, $t(45) = -1.37$, $p = .178$, $d = 0.128$). After grouping, the colors of t-shirts of the two groups were digitally altered to be blue or red. Neutral faces of the remaining ten men were manipulated to simulate infectiousness by paling the skin tone and adding one of five different kinds of facial blemishes intended to mimic pox and ulcers. Based on a second pilot study ($N = 17$), in which participants selected which face out of five pairs (two faces with same type of blemishes were paired together) looked sicker, we split the faces into two groups. The colors of the t-shirts of the two infectious groups were also changed to red and blue (see Fig. 1 for the example faces of each threat/group combination).

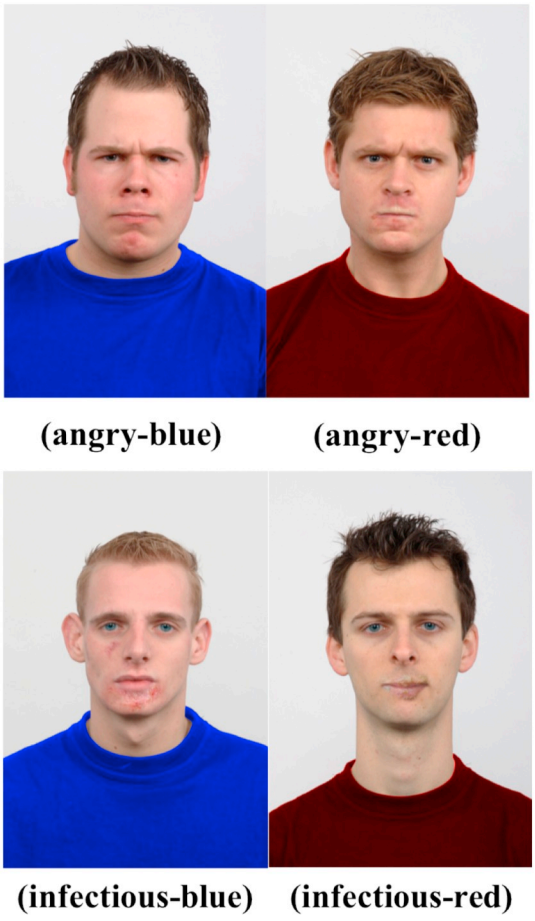

Fig. 1. Example angry and infectious faces.

2.5. Single Category Implicit Associations Test (SC-IAT)

The SC-IAT is a modification of the traditional Implicit Association Test (IAT, Greenwald et al., 1998), which is especially designed to measure the strength of evaluative associations toward a single target (Karpinski and Steinman, 2006). In the present study, participants performed four SC-IATs. Each test corresponded to a different target, which respectively included male faces of angry-red-group, angry-blue-group, infectious-red-group or infectious-blue-group. Following the SC-IAT procedure of Karpinski and Steinman, 2006, in sequence, participants performed a compatible block and an incompatible block, each of which consisted of 24 practice trials and 72 test trials (order of the two blocks was counterbalanced between subjects). In each trial, either a single Dutch word or a male face was presented at the center of the screen. The Dutch words were either positive: e.g., "mooi" (beautiful), "uitstekend" (excellent), or negative: e.g., "ramp" (disaster), "ranzig" (nasty). When words were displayed on the screen, participants were instructed to indicate the word's valence (i.e., positive vs. negative) as quickly and correctly as possible by pressing the corresponding key (E or I) (the correspondence between keys and valences were randomly assigned in each block). When a face was shown on the screen, participants did not make a judgment of the face. Instead, participants had to press either the response-key associated with the positive category (compatible block), or the response-key associated with the negative category (incompatible block) as quickly and correctly as possible. To prevent response biases (i.e., where one response-key is more frequently associated with correct responses than the other), faces, positive words, and negative words were presented randomly in a ratio of 7:7:10 in compatible blocks and a ratio of 7:10:7 in incompatible blocks (Karpinski and Steinman, 2006). To ensure automatic responses, participants only had 1250 ms to provide an answer (they received a message for late or incorrect responses). Implicit bias was assessed by calculating the difference in latencies between the compatible and incompatible blocks. That is, quicker response times when faces had to be categorized with the same response-key as positive words (as compared to negative words) reflected more positive implicit attitudes toward the faces.

2.6. Pathogen disgust sensitivity

Pathogen disgust sensitivity (PDS) was assessed using the Three Domain Disgust Scale (TDDS, Tybur et al., 2009), which measures individual difference on sensitivity to pathogen, sexual and moral disgust across 21 items on a 7-point Likert-type scale, from 1 (Not at all disgusting) to 7 (Extremely disgusting). We used the pathogen domain subscale (7 items) as the indicator of PDS (Cronbach's $\alpha = 0.80$), which does not vary as a function of hormonal changes across the menstrual cycle (Jones et al., 2018). We hypothesized that PDS would negatively predict attitudes toward infectious faces, especially infectious faces from outgroups.

2.7. Hormone measures

Saliva samples were collected via passive drool and, after collection, were frozen. After data collection finished, they were shipped on dry ice to the Kirschbaum Lab at Technical University of Dresden, Germany, where estradiol and progesterone were analyzed using a 17β-estradiol Luminescence Immunoassay kit and a progesterone Luminescence

Immunoassay kit respectively. The intra- and inter-assay CVs were below 12% for both estradiol and progesterone.

The ratio of estradiol to progesterone (i.e., E/P ratio) predicts fertility better than does either hormone in isolation (Baird et al., 1991), and some work suggests that it predicts within-participant changes in mating-relevant behaviors better than do either hormone in isolation (Eisenbruch et al., 2015; Wang et al., 2014). Hence, E/P ratio was the main predictor in the present study. Raw E/P ratio was calculated by dividing raw estradiol (mean = 6.59 pg/mL, SD = 3.06 pg/mL) by raw progesterone (mean = 135.52 pg/mL, SD = 115.08 pg/mL). Six outlier observations (outside 3SD) were excluded from the analysis. Variation of raw E/P ratios ($M = 0.07$, $SD = 0.03$) across four test sessions were calculated. First, the maximum and minimum E/P ratios across four sessions for each participant were first calculated, and then the calculated maximum and minimum E/P ratios were averaged across participants. Here is the average range of raw E/P ratio across four sessions: $M_{max} = 0.11$, $SD_{max} = 0.06$; $M_{min} = 0.03$, $SD_{min} = 0.02$. To facilitate calculations, raw E/P ratio was then centered on the mean of each participant and scaled from −0.5 to 0.5 in the mixed models (Jones et al., 2018).

In the literature, log-transformation of hormonal measures are commonly applied (Jones, 1996). Therefore, in the supplementary materials, we also used log-transformation as an alternative analytic approach to hormone measures (see supplementary materials for models with log-transformed hormones). The results of models with log-transformed hormones were similar to those with non-log-transformed hormones.

3. Results

The SC-IAT *D*-scores were computed according to Karpinski and Steinman's (2006) scoring algorithm. That is, practice trials and non-responses were discarded, responses faster than 350 ms or slower than 1250 ms were eliminated, and incorrect responses were replaced with the block mean plus a 400 ms penalty. After these corrections, the average response times of compatible block (target + positive word) was subtracted from the average response times of the incompatible block (target + negative word). This difference was then divided by the standard deviation of the all correct latencies in the two blocks. Accordingly, a larger *D*-score indicates a more positive evaluation toward the target.

To test the within-subject effects of hormone levels on explicit attitudes toward intergroup threat faces, we followed a multilevel modeling approach using R (R Core Team, 2013), including the packages of lme4 (Bates et al., 2014) and lmerTest (Kuznetsova et al., 2015). In the first model (see Table 1), implicit attitudes were regressed on E/P ratio, facial expression (angry = −0.5, infectious = 0.5), facial group (ingroup = 0.5, outgroup = −0.5), and their interactions. We also controlled for the effect of participants group (red perceiver = −0.5, blue perceiver = 0.5) and session. Random intercepts were specified for participants, as were random slopes of the effects of E/P ratio, target group membership, and target threats (similar effects were observed for analyses with and without outliers, see Supplementary Materials for full models and models without excluding outliers).

Table 1
Predicting biases with E/P ratio, facial expression, facial group and their interactions (controlling for participant group and session).

	Estimate	SE	*t*	*p*
(Intercept)	−0.144	0.04	−3.53	0.001
E/P ratio	−0.003	0.20	−0.02	0.988
Expression	0.016	0.02	0.70	0.485
Facial group	0.017	0.02	0.72	0.472
Participant group	0.053	0.04	1.28	0.206
Session	0.012	0.01	0.87	0.386
E/P ratio × expression	0.621	0.29	2.14	0.033
E/P ratio × facial group	0.367	0.29	1.27	0.205
expression × facial group	−0.050	0.05	−1.05	0.295
E/P ratio × expression × facial group	−0.334	0.60	−0.56	0.577

First, the intercept differed from zero (estimate = −0.14, $t = -3.53$, $p = .001$), which indicates that women had negative biases against both angry and infectious faces. Next, there was a significant interaction between E/P ratio and facial expression (estimate = 0.62, $t = 2.14$, $p = .033$), which is consistent with the hypothesis described above – E/P ratio influenced biases against angry and infectious faces differently (see Fig. 2). To test the hypotheses that E/P ratio positively predicts biases against angry faces, but negatively predicts biases against infectious faces, we tested simple slopes of E/P ratio on biases against angry faces and infectious faces separately. Inconsistent with these hypotheses, neither slope differed from zero (estimate = −0.32, $t = -1.35$, $p = .181$, and, estimate = 0.31, $t = 1.27$, $p = .206$, for biases against angry and infectious faces, respectively), even though they were in the predicted opposite directions. Next, to test the hypotheses that women would show greater bias against angry faces than infectious faces at higher levels of E/P ratio, but show greater bias against infectious faces than angry faces at lower levels of E/P ratio, we further probed the interaction by computing the average within-participant standard deviation change in E/P ratio, and we added and subtracted this value from participant-centered E/P ratio. These analyses showed that women expressed greater bias against angry faces than infectious faces at higher levels of E/P ratio (1 SD above), estimate = 0.07, $t = 2.01$, $p = .045$. However, there was no difference between biases against angry and infectious faces at low levels of E/P ratio (1 SD below), estimate = −0.03, $t = -1.03$, $p = .306$.

Other results lent no support to the hypotheses that E/P ratio relates to biases against outgroup men or that group membership moderates biases against angry and infectious male faces. The interaction between E/P ratio and group membership was not significant, estimate = 0.37, $t = 1.27$, $p = .205$. In addition, the interaction between E/P ratio and facial expression was not moderated by group membership, estimate = −0.33, $t = -0.56$, $p = .577$.

To test the hypothesis that pathogen disgust sensitivity negatively predicts attitudes toward infectious faces, especially faces from outgroups, we added PDS in the next model. Inconsistent with this hypothesis, results showed a non-significant effect of PDS (estimate = −0.13, $t = -1.01$, $p = .315$) and no interactions between PDS, facial group and facial expressions (all $ps > 0.10$). After adding PDS, the interaction between E/P ratio and facial expression remained significant (estimate = 0.74, $t = 2.40$, $p = .017$). Again, there were no effects of group membership (all $ps > 0.05$).

As suggested by an anonymous reviewer, since progesterone in isolation (rather than in tandem with estradiol) might more strongly covary with vulnerability to infection, we also conducted an exploratory model to directly test the effects of single hormones – estradiol and progesterone separately in contrast with E/P ratio – on biases against infectious faces (see Table 2). The model revealed no statistically significant effects of progesterone (estimate = −0.20, $t = -1.15$, $p = .266$) or estradiol (estimate = 0.24, $t = 1.95$, $p = .053$).

4. General discussion

The present study was designed to investigate how women's implicit biases against violent and pathogen threats shift as a function of the reproductive hormones that vary across women's menstrual cycle. In an attempt to replicate McDonald et al. (2011), we also tested how these attitudes varied across the group membership of the men. We found that changes in E/P ratio moderated the difference in women's implicit bias against angry faces and infectious faces. However, the relationship between E/P ratio and bias against male faces did not differ from zero for angry or infectious faces, and group membership did not moderate this effect.

Here, we test the hypothesis that women's responses to cues of violence and pathogen threats vary with fluctuations in reproductive hormones was not confirmed. The slopes of E/P ratio on biases against angry and infectious faces were not significantly different from zero, which suggested that neither biases against angry faces nor infectious

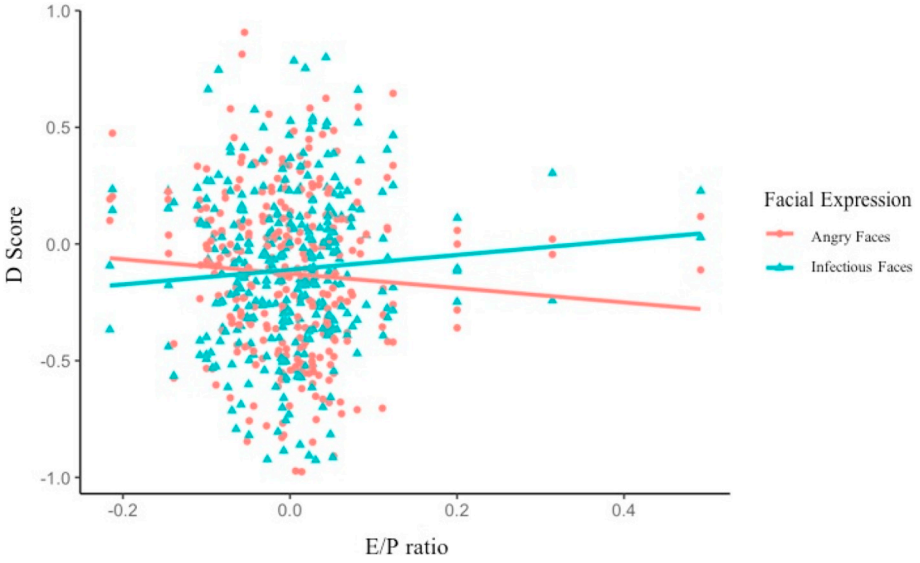

Fig. 2. Interaction between E/P ratio and facial expression on implicit attitudes toward threatening faces. *654 observations were presented* (*41 participant* × *4 sessions* × *2 facial expression* × *2 facial group - missing values*). *More negative D scores indicate greater bias associated with the faces*.

Table 2
Predicting biases against infectious faces with estradiol and progesterone.

	Estimate	SE	*t*	*p*
(Intercept)	−0.116	0.05	−2.24	0.027
Estradiol	0.238	0.12	1.95	0.053
Progesterone	−0.196	0.17	−1.15	0.266
Session	0.002	0.02	0.14	0.892

faces changes with E/P ratio. The findings did lend some support to the hypothesis that at different period of women's menstrual cycle, which vary as a function of hormone status, women are more sensitive to different threats. We found that changes in E/P ratio – which, at high levels, coincide with peak fertility, and at low levels coincide with the luteal phase of the menstrual cycle – differentially related to bias against angry and infectious male faces. Specifically, simple effect tests revealed that biases against infectious and angry faces differed at high E/P ratios (i.e., states associated with higher conception probability) but not low E/P ratios (i.e., states associated with the luteal phase of the cycle, when infectability is putatively higher). This finding suggests that though women have a general tendency of avoiding both violence and pathogen threats across the menstrual cycle, the primary threat that women are more negative toward may change with the fluctuation of reproductive hormones across their cycle. When conception risk is high, aggressive men might be more detested than unhealthy men.

The present study partially aimed to replicate and extend findings reported in McDonald et al. (2011), which suggest that women's implicit bias against outgroup men increased with elevated fertility across the menstrual cycle. We used a similar minimal group paradigm (by using a color judgment task) to manipulate group membership, and also used implicit attitudes as dependent measures. In contrast with McDonald et al. – but consistent with Hawkins et al. (2015), who reported no relationship between conception risk and bias against racial outgroups – we found no evidence that intergroup bias relates to women's hormonal status or threat type. We should note that the current study was not intended to be a direct replication of McDonald et al. (2011). However, departures from direct replication were intended as improvements. First, the assessment of reproductive hormones rather than forward counting much improved the validity of conception risk measure. Second, a within-subject design with multiple test sessions afforded greater statistical power than the between-subjects approaches used in earlier work. Both of these modifications are consistent with current best practices in this literature (Gangestad et al., 2016). Given results reported here and by Hawkins et al. (2015), we believe that there is insufficient evidence to confirm an association between conception risk and bias toward outgroup men. A meta-analysis of the effects found in this growing literature would be recommended for future study.

Before closing, we will briefly outline limitations and prospects for future research. First, like McDonald et al. (2011), the present study did not include a manipulation check to see if the minimal-group manipulation worked in our study. The null effect for group membership we observed in the present study may be due to a weak or absent categorization effect. Future studies could further test the validity of the minimal-group manipulation, for example by asking participants to indicate their identification with the assigned group at the end of the study (Grieve and Hogg, 1999; Richter, Over, & Dunham, 2016), or ask participants to indicate how much control they felt they had in determining their group membership in the minimal-group manipulation (Platow et al., 1990; Reynolds et al., 2007). Another limitation of the present study is that we did not ask participants how physically threatening or infectious the faces looked. Such idiosyncratic perceptions might moderate the relationship between reproductive hormones and biases. To address this issue, we ran a small-scale study ($N = 47$) to re-evaluate the threatening faces used in the present study. We found that angry faces ($M = 5.84$, $SD = 2.09$) were rated as more physically threatening than sick faces ($M = 2.52$, $SD = 1.62$), $t(46) = 9.90$, $p < .001$, $d = 1.769$, and sick faces ($M = 6.10$, $SD = 1.61$) were rated as more sick than angry faces ($M = 1.91$, $SD = 1.06$), $t(46) = -17.57$, $p < .001$, $d = 3.022$. The results indicate that the face manipulations were perceived as intended. Last, by using SC-IATs, we were able to compare changes of women's biases against male faces with different threats across their menstrual cycle. However, as suggested by an anonymous reviewer, we did not test how women's implicit attitudes toward non-threatening male faces changes across menstrual cycle, which may have altered the range of women's IAT responses. Neutral faces and female faces could be used in future studies to test whether biases against broadly threatening faces versus non-threatening faces vary with reproductive hormones.

5. Conclusion

Taken together, results from the present study provide no evidence that women's implicit attitudes toward violence threats nor pathogen

threats changes with the change of reproductive hormones across women's menstrual cycle. However, we did find that at high levels of E/P ratios, women show greater biases against men who pose a violence threat than men who pose a pathogen threat. This effect should be interpreted cautiously, as should the observed interaction between E/P ratio and threat type, given the lack of statistical significance of other simple effects. Further, the present research does not support previous findings on the influence of women's reproductive hormones on intergroup biases. Further work is clearly needed to better understand what effects (if any) reproductive hormones have on intergroup biases and threat management. We hope that this study can act as an initial step in a new generation of methodologically improved studies on the influence of reproductive hormones on implicit social cognition.

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Appendix A. Supplementary data

Supplemental information (e.g., data files and analysis scripts) available at: https://osf.io/e4g5b/?view_only=54f03c990d4e46dda02095c4d0e4a77f. Supplementary data to this article can be found online at doi: https://doi.org/10.1016/j.yhbeh.2019.06.012.

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